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RANDOM RESPONSE ANALYSIS OF A TYPICAL AERO SPACEPLATE STRUCTURE

B SANDHYA REDDY[1] & A. PURUSHOTHAM[2]

[1]Research Scholar, Department of Mechanical Engineering, Sree Nidhi Institute of Science & Technology, Hyderabad, Andhra Pradesh, India

[2]Professor, Department of Mechanical Engineering, Sree Nidhi Institute of Science & Technology, Hyderabad, Andhra Pradesh, India

ABSTRACT

Structural plates are used in many engineering applications that include aerospace, ship industries and defense products like pressure vessels, body of missiles etc. These plates are under go severe vibrations when dynamic loads act on them. The plate structure undergoes vibrations when it is used in many applications such as aircraft cabins, bodies of rockets and missiles. The paper aims at finding the natural frequencies of a typical plate structure that is used in a typical aero-space structure. For this purpose, plates are modeled and analyzed in FEMAP software first and then fundamental frequencies are carried out analytically on the plates to validate simulation results. This paper describes elaborately how FEMAP modal analysis is used to study the dynamic behavior (natural frequencies & mode shapes) of the plates. The modal frequency results obtained from FEMAP have been correlated with the Analytical values. Four different types of plates having different thickness and material properties have been taken for the present investigation. The simulation values of four Different combinations of plates are also correlated with analytically evaluated values.

KEYWORDS: Random Vibrations, Fundamental Frequency, Response, FEMAP

INTRODUCTION

Every product, machine and structures are subject to vibrations in the real operating conditions. The vibrations are produced due to dynamic forces acting on the machine, internal forces within the system and environmental conditions. The adverse effects of these vibrations can range from negligible to catastrophic depending upon the severity of the disturbances and the sensitivity of the equipment. Aerospace vehicles are designed, developed and produced to meet the system performance, for both civil and military applications such as satellite communications, mineral and ground water survey, weather forecast or destroying the enemy installations during war[1].. The aero systems have to withstand a wide variety of ground and aero loads encountered during various phases of development, storage; field deployment and flight till the mission objectives are achieved. During all these phases, different types of environmental loads both natural and induced are encountered by the aerospace vehicles. Dynamic parameters such as shock, vibration and acoustic loads in the induced environments dominate and affect the performance of both subsystem and complete system [1]. In order to withstand these dynamic environments the entire aerospace vehicles-i.e. aircraft, missiles or launch vehicles are all designed with adequate safety margins with optimum performance to meet specified tasks. The aim of this paper is to validate the design for different types of PLATES (aero-space structure) for dynamic environment by analyzing the modal frequencies using modal analysis and verification with Analytical values separately for each plate. The paper aims at finding the natural frequencies of different plates (aero-space structure) for given boundary conditions and also the random response results are calculated for each type of plate separately, which is performed as ‘post processing’ to the previously completed Frequency Response Analysis. The paper is organized in the following manner: Section 2.0 describes the

Analysis methodology that includes modeling and FEMAP analysis. The results obtained from the analytical expression and FEMAP method along with discussion are included in the section 3.0.Section 4.0 draws conclusions.

ANALYSIS METHODOLOGY

The structure consists of a bottom plate which is fixed to the frame and top plate which will vibrate. The bottom plate is made up of steel and top plates are made up of aluminum. The details material properties and geometry of plates are shown in the table 1

Table 1: Details of Geometry and Materials of Plates

Material	Steel Plate	Aluminum Plate
Young's modulus	200 GPa	70 GPa
Density	7800 kg/m³	2666 kg/m³
Poisons ratio	0.25	0.35
Dimensions	250mm×100mm x5mm	Plate 1:250 X 100 X 1.5mm Plate 2:250 X 100 X 2.5mm Plate 3:250 X 100 X 3.0mm Plate 4:250 X 100 X 5.0mm

The methodology deals with (i) the modeling of rectangular plate (aero-space structure) by using solid works for dynamic environment and (ii) analysis of the designed plates using FEMAP to know the vibration responses i.e., normal modes or Eigen values and Random response. The analysis process also decides the stability of the design. The modeling stage is done in three stages and they are (i) Designing of a top part of rectangular plate, (ii) Designing of a bottom part of rectangular plate and (iii) Assembly of two parts and analysis of assembled component. All these three stages are shown in the Figure 1.

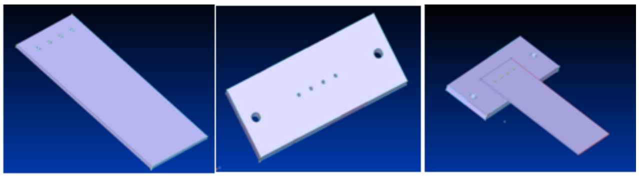

Figure 1: Individual Plates and Assembly

The assembled structure is imported to FEMAP in parasolid format which is shown in Figure 2

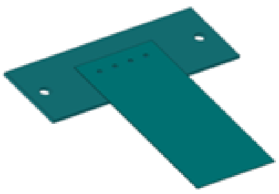

Figure 2: Assembled Plate Structure in FEMAP

After importing in FEMAP steps to fallow are given below:

- Creating geometry- mid surfaces
- Selection of Material & Property Element type
- Meshing- specify mesh control & geometry
- Apply Constraints@ nodal

- Give functions
- Apply load at nodal point
- Create groups
- Mention the Type of Analysis

The FEMAP gives vibration modes shapes as shown in Figure 3. Through the post processing the amplitude variations can be studied.

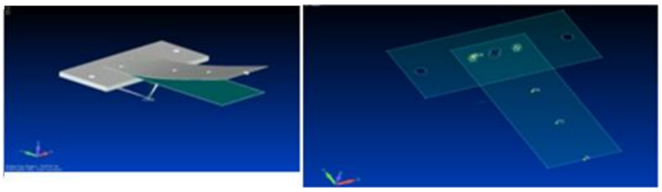

Figure 3: The Mode Shapes of a the Plate Assembly

RESULTS AND DISCUSSIONS

The Rayleigh method equations are being used to determine the fundamental bending frequencies of the plate assembly. The equation is given below:

$f_n = (0.583/a^2)\times \sqrt{D/\rho h}$ (1)

Where $D = Eh^3/ (12 \times (1-\mu^2))$

E = Young's modulus of the material N/mm2, h = Thickness of the rectangular plate in mm

ρ = Density of the material Ns^2 / mm^4 μ = poisons ratio

a = Length of the rectangular plate b= height of rectangular plate.

f_n = natural frequency.

Analytically the natural frequencies are being computed data available in Table 1. The boundary conditions imposed on top plate is: Fixed-Free-Free-Free. Four plates have been modeled and analyzed by the methodology described in section 2 and the natural frequencies are obtained. The values of natural frequencies of top plate obtained from FEMAP are shown in table 2. The comparative values of fundamental frequency obtained with both methods: Analytical and FEMAP are shown in Table 3

Table 2: Natural Frequencies of Various Top Plates Obtained in FEMAP

Modes	1	2	3	4	5	6	7	8	9	10
Frequencies of plate 1 (HZ)	18.926	98.772	118.110	315.401	329.121	586.552	635.404	698.377	849.377	938.743
Frequencies of plate 2(HZ)	35.321	189.150	219.408	605.909	607.907	1117.923	1131.67	1165.397	1346.169	1576.34
Frequencies of plate 3(HZ)	48.472	228.216	300.492	731.107	837.617	1156.772	1364.533	1365.095	1597.665	1679.394
Frequencies of plate 4 (HZ)	72.605	373.787	452.983	1169.494	1195.888	1261.04	2228.776	2423.081	2729.782	3254.906

Table 3: Analytical Values and FEMAP (Numerical) Values of Fundamental Frequency

Type of Plate	Analytical Values (Hz)	FEMAP Values (Hz)
Plate-1(Steel 250×100×1.5mm)	18.135 Hz	18.926 Hz
Plate-2(Aluminum 250×100×2.5mm)	35.932 Hz	35.321 Hz
Plate-3 (Aluminum 250×100×3mm)	43.392 Hz	48.472 Hz
Plate-4(Aluminum250×100×5mm)	67.329 Hz	72.605 Hz

Figure 4 shows the response plot obtained from FEMAP where Natural Frequencies are varied from 20 to 2000Hz. It is found that the maximum value is 10mm in all plates. It is also observed that the values of fundamental frequency obtained in Analytical and numerical are all most coincide with the small variation of 1%.

The mode shape plots at each frequency for different plots are shown in Figure 4

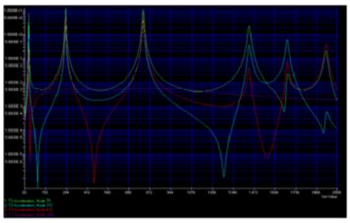

Figure 4: The Amplitude Response Curves of Four Plates at various Natural Frequencies

CONCLUSIONS

In this paper, a plate Structure consisting of two plates is takento study the random vibration. Most ofaero-space structures use plate structure and subjected to random excitation. The natural frequencies of four different plate structures are being evaluated using softwares Solid Works and FEMAP. The fundamental frequencies four different plate structures also computed with Reynold plate bending equation. Then a comparison is made between Analytical and FEMAP values and they are almost coincided. FEMAP also helped to study the vibration amplitude of top plate with reference to bottom plate which is rigid as well as thick. The simulation studies are made on four plates of different thickness and it is found that the amplitudes are low in thick plate at low frequencies and high at higher frequencies.

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